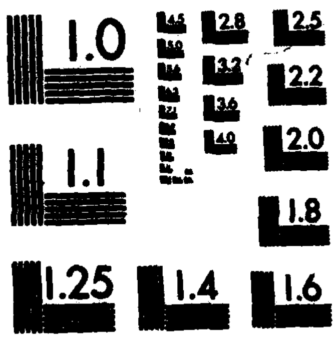
AD-A124 749 ANALYSIS OF F-16 RADAR DISCREPANCIES(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING K A RICHE DEC 82 AFIT/GE/EE/82D-56 1/1

UNCLASSIFIED F/G 15/5 NL

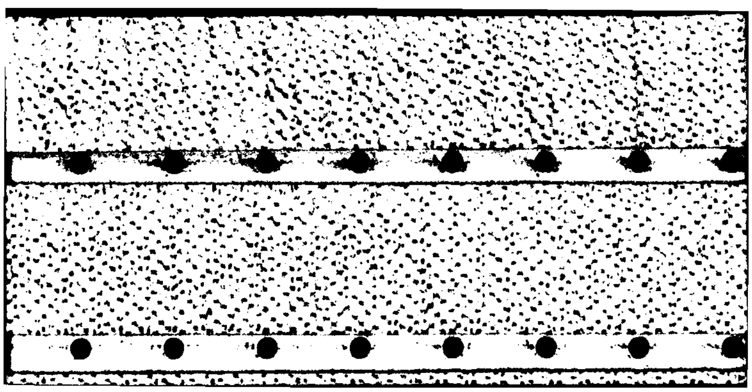
END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



Analysis of F-16

Radar Discrepancies

Thesis

AFIT/GE/EE/82D-56

Kim A. Riche

Capt USAF

AFIT/GE/EE/82D-56

Analysis of F-16

Radar Discrepancies

Thesis

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

by

Kim A. Riche, B.S.

Capt USAF

Graduate Engineering

December 1982

Approved for public release; distribution unlimited

Preface

This research was an effort to obtain information about the frequency of occurrence of radar system write-ups on the F-16 aircraft. It was undertaken in conjunction with a study by the Air Force Human Resources Laboratory, Wright-Patterson AFB, Ohio and Westinghouse Electric Corporation. The results of this research will hopefully assist the Air Force in determining areas where the maintenance decision process can be improved, in the long run saving money and increasing mission capability.

The author wishes to thank Mr. Russell M. Genet, Air Force Human Resources Laboratory, Wright-Patterson AFB, Ohio for his guidance during this research, and Mr. Leroy N. Russell, Dynamics Research Corporation, Dayton, Ohio for his enthusiastic support and assistance in obtaining the required data.

Kim A. Riche

Contents

List of Figures

Abstract

One hundred and eight aircraft were randomly selected from three USAF F-16 bases and examined over the time period 1 Dec 81 to 15 Aug 82. These aircraft included 63 single-seat F-16As and 45 two-seat F-16Bs and encompassed 8,525 sorties and 748 radar system write-ups. Programs supported by the Statistical Package for the Social Sciences (SPSS) were run on the data. Of the 748 discrepancies, over one-third of them occurred within three sorties of each other and half within six sorties. Sixteen percent of all aircraft which had a discrepancy within three sorties had another write-up within the next three sorties. Designated repeat/recurring write-ups represented one-third of all the instances in which the write-up separation interval was three sorties or less. This is an indication that maintenance is unable to correct equipment failures as they occur, most likely because the false alarm rate is too high and maintenance is unable to duplicate the error conditions on the ground for correct error diagnosis.

I. INTRODUCTION

Recent advances in technology and Air Force requirements have given birth to a new generation of aircraft avionics systems. These new systems provide crew members with more information, more options and more capability than ever before. This translates into a higher sortie effectiveness (efficiency) and reduced workloads for the crew member accomplishing the same tasks. In the case of fighter aircraft, this also means an increase in the survivability rates during enemy engagements and higher accuracy in ordinance delivery.

Background

The Air Force currently has in its inventory several aircraft which use this new technology, including the E-3A, F-15 and F-16. Although these new systems have brought the desired improvements in capability and performance, they have also brought additional maintenance problems. Besides being higher in cost, they are extremely complicated, requiring complex maintenance equipment. It is not feasible to use highly qualified technicians for routine maintenance and repair because the Air Force's supply of these individuals is limited, primarily due to economic and manning restrictions. Therefore, the maintenance philosophy has been altered from one of "smart man, dumb machine" to "smart machine, dumb man". There have been several advances in technology which make this philosophy possible, specifically self-test and built-in-test functions and automated testing procedures (Ref 4:1).

The self-test (ST) and built-in-test (BIT) functions provide a means of having an avionics unit test itself while it is operating in its normal environment. Self-test has been defined as a "continuous, noninterruptive fault detection function that is mode oriented", also referred to as fault detection (FD). Built-in-test has been defined as a "hierarchical group of interruptive tests that detect and isolate failures to a single line replaceable unit (LRU)", also called fault isolation (FI) (Ref 2:63,67).

Automated testing, as referred to in this research, is the computerized testing of certain avionics units in a maintenance shop by relatively low skill level technicians. They communicate information to a computer-controlled test station and in return receive test results and instructions. This test equipment is referred to as Automatic Test Equipment (ATE), and is usually located in the Avionics Intermediate Shop (AIS) where Intermediate-Level (I-Level) maintenance is performed.

There are several negative aspects to self-test, built-in-test and automated testing. Using current technology, it is not possible to achieve the extremely high probabilities of fault detection and fault isolation desired without acccepting a high false alarm rate. Measuring the actual number of false alarms is difficult because the measurement is clouded by the fact that actual failures can masquerade as false alarms (intermittent faults) which are predominantly the result of BIT specifications and designs being tailored to an ideal (noise-free) world (Ref 6:iii,34-46).

High false alarm rates significantly affect the maintenance process. The technicians learn to live with them, often ignoring a failure condition even if it is (unknowingly) correct. A study of nine different Air Force systems (Ref 2:7,15) indicate that the unnecessary removal rate of LRUs is on the order of 40% and has been found as high as 89%. A false alarm may indicate a true fault that does not require an immediate correction. It may also indicate a degradation in system performance or capability, particularly if the arrival periods of the false alarms (write-ups) are decreasing. In many cases, invalid indications may be corrected by simply resetting the BIT threshold. However, for a significant reduction in BIT detection errors, tests that are letting too many bad units go undetected need to be tightened up and tests which are identifying too many good units as faulty need to be loosened up, a trade-off between the classic Type I and Type II errors. (Ref 8:15 and Figure 1).

BIT usefulness, the percentage of field problems resolved by using BIT, is significantly degraded by the presence of false alarms. If BIT indicates a momentary signal excursion outside of the test limits, the operator can be reasonably confident that the signal did indeed

		Diagnosed Condition	
		Good	Bad
Actual Condition	Good	Correct	Type I
	Bad	Type II	Correct

Type I : Reject H(O) when it is true

Type II: Accept H(O) when it is false

Fig 1. Error Diagnostics Chart

exceed the specified limit. But more often than not, such anomalous performance is not a manifestation of a fault and it is a mistake to take maintenance action based solely on the BIT indication (Ref 6:vii). When an Organizational-Level (O-Level) technician troubleshoots a system at the aircraft and fails to find the discrepancy which was written up, the result is a Cannot Duplicate (CND) report. Should the decision be made to remove a LRU and send it to the Avionics Intermediate Shop, if the Automatic Test Equipment fails to find anything wrong with the unit then a Re-Test Okay (RTOK) has occurred.

Currently, CND rates average in excess of 40%, with RTOK rates around 30% (Ref 1:1,2:7). These are averages throughout military and commercial aviation. Several problems are associated with these high rates. The most significant consequence of high CND and RTOK rates is that they reduce confidence in BIT as a troubleshooting tool, which causes BIT to be ignored at times even if it is correct. In addition, they result in: 1) increased maintenance costs and rates, 2) overcrowded I-Level maintenance shops, 3) delays in aircraft turnaround, 4) inefficient use of high skill level technicians and 5) reduced mission capability.

As a result of these statistics and the Air Force's own experience with the new systems, the Air Force Human Resources Laboratory (AFHRL) is conducting a pilot study to "develop and test a methodology to identify the causes of diagnostic errors in the maintenance of avionics equipment, quantify their relative contributions, and develop corrective actions" (Ref 1:1). Westinghouse Electric Corporation (WEC) has been contracted to provide an Avionics Diagnostics Pilot Study Plan in pursuit of this objective. It was desired that the system to be investigated be a military system utilizing ST/BIT, with at least two years of operational service. (Past experience indicates that it requires two to three years of operational use to tailor the BIT in a new system to an operational environment and to use it effectively (Ref 2:S-3,6,44)). Additionaly, a system in use at several bases was desired to provide a solid data base.

The F-16 was chosen for the study, with the AN/APG-66 Fire Control Radar the system of primary interest. The radar system is the most critical and complex part of the aircraft avionics package and employs both the ST and BIT diagnostic report capabilities which require maintenance decisions on the part of maintenance personnel. Westinghouse further recommended the Low Power Radio Frequency (LPRF) LRU for specific analysis because it is the most complex LRU in the radar system and has experienced high CND and RTOK rates. Previous studies (Ref 2:27) indicate that the overall F-16 RTOK rate is 25.8%, the CND rate is 45.6%, the fault detection rate (attributable to Self-Test) is 49% and the fault isolation rate (attributable to Built-In-Test) is 69%. The contracted specification for the fire control radar system was detection and isolation to specific LRUs for 95% of all radar malfunctions, with a false alarm rate less than 1% (Ref 2:46). As the Air Force views the performance statistics, the system has not met its contracted specifications.

In order to meet the goals of the pilot study, AFHRL and WEC are developing a model of the maintenance process which will be used to: 1) determine how unnecessary maintenance affects aircraft availability and support costs, 2) identify sensitive decision points in the maintenance process and 3) evaluate suggested improvements (Ref 4:1). To assist in gathering the necessary information, AFHRL sent a team of investigators to MacDill AFB, Florida, where the maintenance process was observed first-hand.

Initial Study

The initial area of study for this thesis was the effect of the "pilot squawk" (maintenance write-up) on the maintenance decision process. After several days of interviewing F-16 pilots and instructors and examining the specific maintenance process at MacDill AFB, it was determined that although the pilot is the only person to observe the performance of the equipment in the actual conditions it is supposed to operate under, once a minimum amount of information is provided to maintenance debriefers further information from the pilot generally does not affect the maintenance process. Essentially, the pilot becomes a binary flag input, indicating malfunction or no malfunction.

Results of the pilot interviews verified certain previous assumptions about the pilot input. Hard failures, multiple intermittent failures, noticeable degradations of performance and maintenance failure codes generated by the self-test and built-in-test functions are written up. Occasional intermittents generally are not written up unless supportive information (computer diagnostic error codes, external observations) is present. Maintenance then gets, as the pilot sees it, only write-ups on known failures. The amount and type of information conveyed to maintenance during the debriefing is highly dependent on the individual pilot, the debriefer and the type of malfunction. As a result, it was not possible to obtain information which would provide a solid data base for analysis and, based upon the information received during the interviews, this particular course of research was terminated.

The technician who goes to the aircraft to see if he can duplicate the fault indication often knows only that a particular malfunction code was reported or that a certain symptom occurred. Actual parameters such as altitude, airspeed, g-loading and outside air temperature are often unknown to the technician, and his procedure is essentially independent of the amount of information provided. When he runs the BIT function on the ground, it is run under conditions very different than those actually experienced in flight. The environmental effect on decision error rates is significant although not as significant as maintenance decision errors and false alarms (Ref 3:4).

If the results of the BIT agree with the discrepancy reported, the appropriate action indicated by the Technical Order is taken. If maintenance can be delayed until after the last sortie of the day without affecting the remaining mission(s), then it most likely will be. Otherwise, if LRU removal is directed, the unit is sent to the AIS. If a spare is available, it is replaced as soon as practical. If there is no spare unit, then maintenance has two alternatives: 1) cannibalize a good unit from another aircraft or 2) place the aircraft in a restricted status which will most likely remove the aircraft from the flying schedule.

Specific action may also be dictated by the previous history of the aircraft. If the discrepancy is occurring for the only time within the last three sorties then normal maintenance procedure is followed. If aircraft history records indicate that the same discrepancy was reported within the last three sorties then the write-up is annotated with an additional maintenance repeat/recurring code of 'C' or 'R'. If the previous write-up does not show a repeat/recurring code then this is the second occurrence and normal maintenance procedures are followed. If, however, a 'C' or 'R' code exists on the preceding discrepancy then this write-up is the third occurrence and policies dictate that positive maintenance be performed. This is an attempt to preclude the intermittent from continually arising and degrading system performance. If flight line maintenance technicians fail to locate a fault at the aircraft, the LRU which is deemed by these technicians to be the most likely cause of the problem is removed and sent to the I-Level maintenance shop with the hope that this will correct the malfunction.

II. STATEMENT OF THE PROBLEM

The high CND, RTOK and false alarm rates of the F-16 radar system have a significant impact on the Air Force mission and capability. In conjunction with the Avionics Diagnostic Pilot Study Plan, it was believed that an analysis of the radar discrepancies would be beneficial. Specifically, this would include a study of the rates of occurrence of radar system write-ups in general, the characteristics of their occurrences and the characteristics of the repeat/recurring write-ups. Once the data were obtained and analyzed, a simple model portraying the probability of a radar discrepancy on a given sortie could be constructed. The remainder of this thesis is the report on this effort at analysis of the F-16 radar system discrepancies.

Approach

The F-16 maintenance records are maintained on a computer system known as the Centralized Data System (CDS) by Dynamics Research Corporation (DRC), a civilian contractor. This system is a significant improvement over previous data storage methods in that it provides access to specific information within 24 hours from the time that it is entered into the system. In addition, users have access to the F-16 maintenance records of all USAF F-16 bases which are presently connected to the system.

Data are organized in a complicated structure in the

CDS, somewhat similar to a multiple linked-record format but with many inter-connections. In order to simplify data access for the everyday user, standard queries have been created by DRC. A standard query initially modified by Mr. L. Russell of DRC and provided by him was further modified in order to obtain the required information for this study. This particular program provides a listing of all sorties flown and the associated, if any, maintenance malfunction codes. (Appendix A).

To provide a data base for the analysis, records of 108 aircraft which were selected at random from 3 bases were obtained, which encompassed 9,525 sorties. This population included both the single-seat F-16A and the two-seat F-16B, the B model being the trainer version. The actual distribution of aircraft is shown in Appendix B. These aircraft represent approximately one-third of the number of aircraft stationed at these three bases during the time period 1 December 1981 to 15 August 1982, the time frame for which data were obtained.

The information from the Centralized Data System was then recoded into a format suitable for processing by various programs supported by the Statistical Package for the Social Sciences (SPSS). A separate program was written to analyze the arrival characteristics of the data and of the repeat/recurring discrepancies.

Of particular interest to the AFHRL for their pilot study is the number of sorties separating multiple consecutive write-ups. The original data represent the sorties separating two write-ups. Sorties separating three write-ups can be analyzed using the following approach. Determine the first (reference) write-up. Identify i as the number of sorties separating the first write-up from the next (second) write-up and j as the number of sorties separating the second write-up from the third. An analysis can then be made on the ordered pairs (i,j). Extending this process to one more write-up, an analysis can also be made of the ordered triples (i,j,k), where k is the number of sorties separating the third write-up from the fourth. These results were then used to create a simple model for use by the AFHRL in their study.

III. RESULTS

The data maintained by the Centralized Data System are, in certain time frames, incomplete and occasionally inconsistent across data records. For this research, the data range was restricted to the nine and one-half month period beginning 1 December 1981, primarily because this was the break point for current on-line data and data which needed to be accessed separately through historical records. In addition to sporadic omissions of data, there was a one and one-half month break in the records for aircraft from one base which could not be recovered using any of the other data records available.

Pertinent data were used from the first occurrence of a radar system write-up to the last occurrence in the specified time frame. The number of sorties from 1 Dec 81 to the first write-up, and from the last write-up to 15 Aug 82, were ignored because the actual number of sorties separating the last and first discrepancies outside the time frame was unknown.

The 8,525 sorties included in this study resulted in 748 occurrences of radar write-ups. The SPSS programs showed that the average separation between write-ups at all three bases was 11.4 sorties, with a minimum of 1 (i.e., occurrence on the next sortie) and a maximum of 135. The most frequently observed separation (the mode) was 1, occurring 14.8% of the time.

Probably the most meaningful statistic, however, is the median, that number which has 50% of the write-ups on either side of it. The median for the overall population was 6.4. Approximately 35% of all write-ups occurred within 3 sorties of another discrepancy, 50% within 6 sorties and 66% within 10 sorties. For a complete breakdown by base and model, see Appendices C and D.

The distribution of the probabilities of having i sortie separations between write-ups initially appears to be an exponentially decreasing function. Further analysis using linear regression techniques reveals that this particular distribution is approximated very closely by a function of the form

$$P(i) = -0.131i + 12.761/i + 3.371$$

where i is the number of sorties until the next write-up and P(i) is the probability of that occurrence, in percent. (The R-Square correlation value for this approximation is 0.9658). A graph of the actual distribution and this approximation are shown in Figure 2.

The median number of sorties separating radar write-ups at Nellis is 4.8, significantly less than the medians for Hill (7.1) and MacDill (6.4). This might be explained by the fact that Nellis' operation is considerably newer than either of the others and, as a consequence, the experience level of their maintenance technicians may be lower.

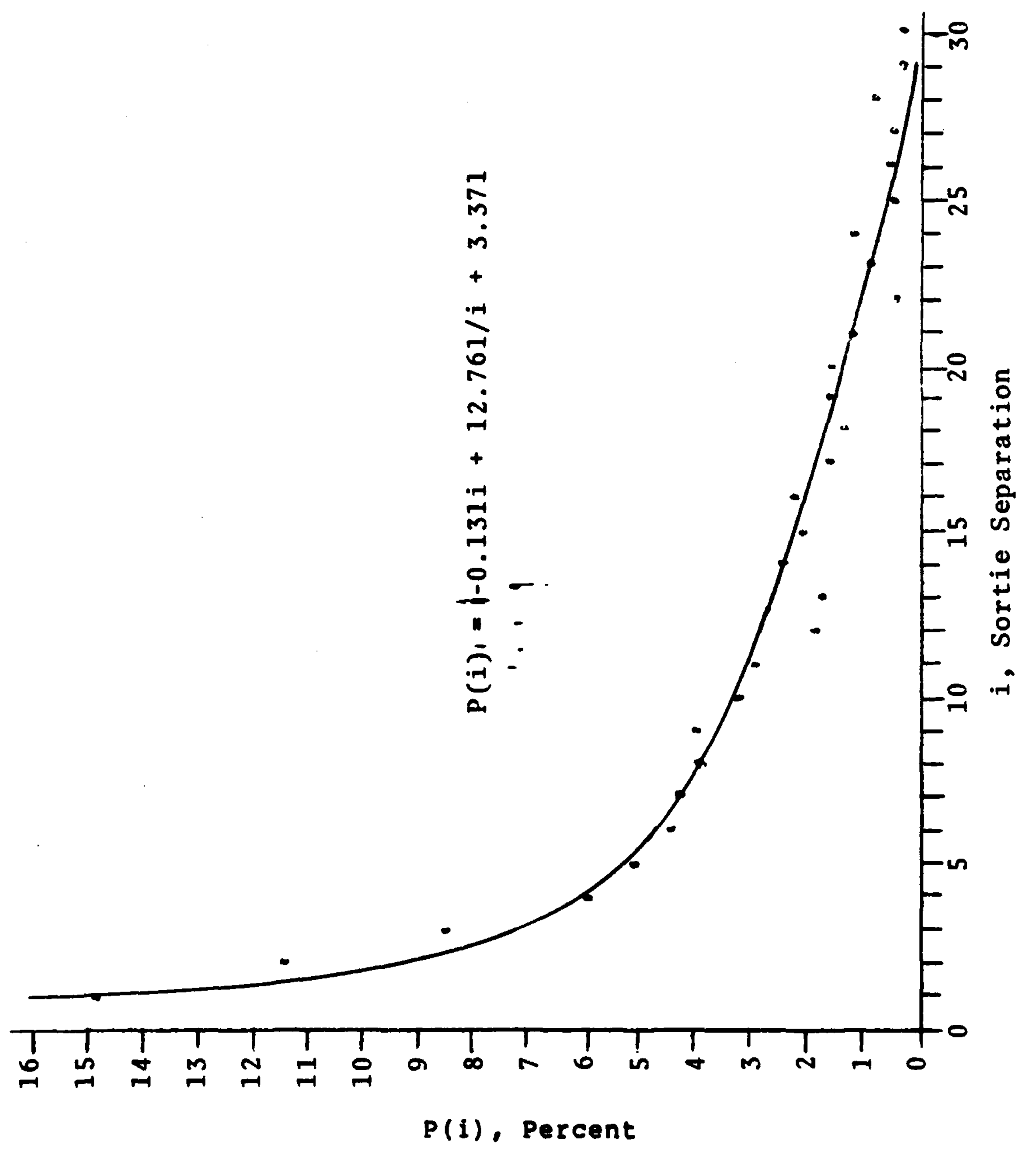


Fig 2. Distribution of Sortie Separations, All Bases

Incorrect maintenance decisions might then occur more frequently.

Also of significance is that, in general, the A model discrepancies occurred more often than those for the B model (every 5.9 as opposed to 7.2). This was also true when comparing the models at individual bases, except at Nellis. The difference could be explained by the following. For most training sorties, pilots usually fly in the A model. The B model is used primarily when the training syllabus requires an instructor to fly in the same aircraft. This occurs normally when a pilot is being introduced to a new phase of flying (e.g., transition, air-to-air, air-to-ground). Once the pilot has obtained a minimum level of proficiency, further training is normally obtained using the A model. Also, total system utilization in the B model does not occur as often as as it does in the A model because of the specialization of the B model sorties. As a result, it is possible for discrepancies to occur more often in the A model than in the B model. It is worth mentioning that for scheduling and training flexibility a B model aircraft is often flown single-seat when an A model would suffice. This explanation then is offered purely as a supposition.

Analysis of the ordered pairs (i,j), as previously described, yields interesting results. Of the 540 total sortie pairs involved, 107 which had a radar discrepancy within three sorties of a reference write-up had another within the next three, or 16.7%. Twenty-seven percent which had a write-up within five sorties had one again within the next five. Figure 3 is a partial matrix extracted from the complete listing in Appendix E.

j, (Following Interval)

i, (Initial Interval)	1	2	3	4	5	6	7	8	9	10
1	18	21	10	3	4	4	4	3	3	1
2	15	16	7	4	3	6	1	3	4	2
3	8	6	6	6	4	0	2	4	0	1
4	8	2	3	4	3	1	2	3	3	0
5	4	2	5	2	4	1	3	3	0	1
6	6	4	3	3	0	0	2	1	2	0
7	6	2	0	2	1	0	1	2	0	1
8	4	2	4	1	0	0	0	1	0	3
9	1	5	2	0	2	2	2	1	1	1
10	3	1	3	0	1	2	1	0	1	1

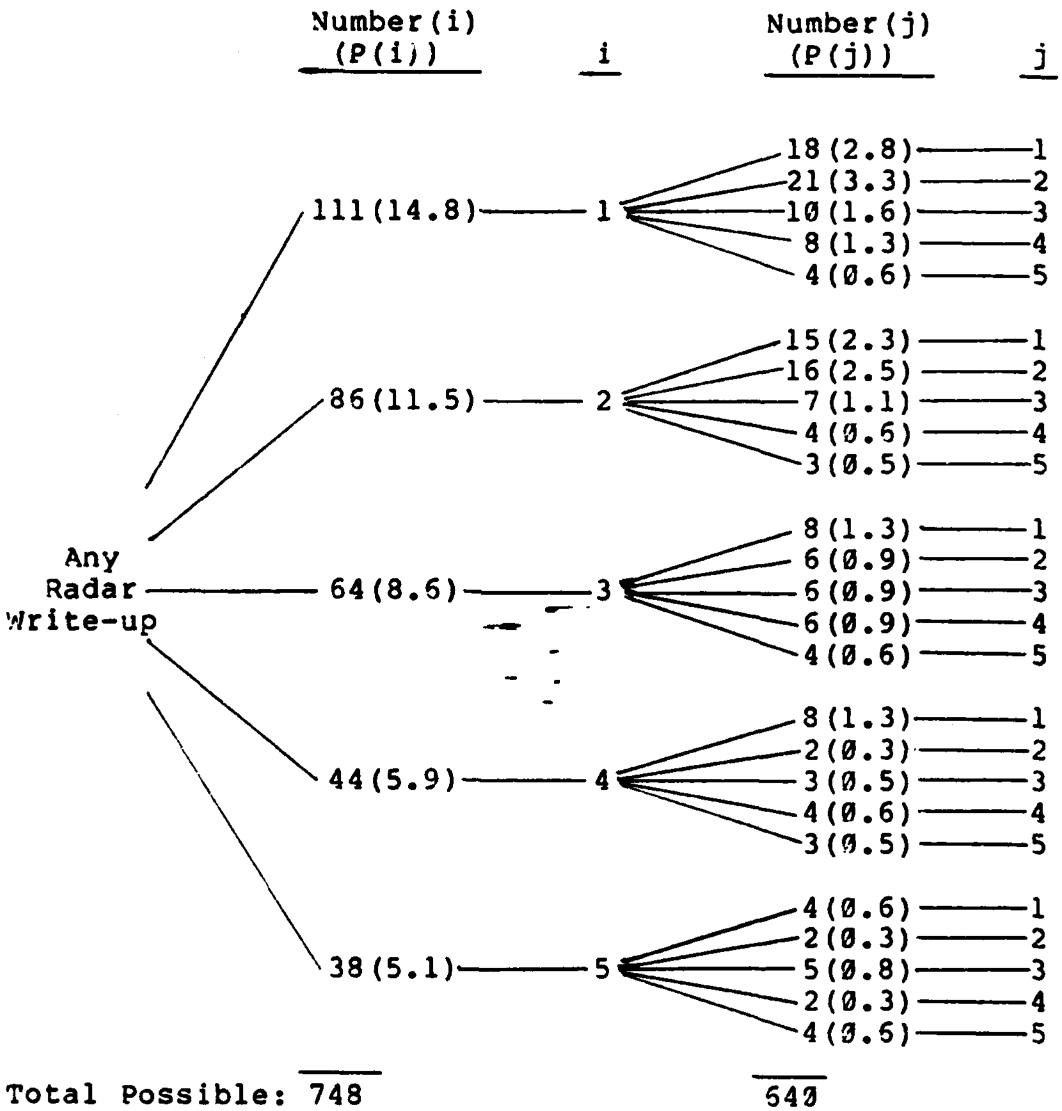
i,j: number of sorties between radar write-ups

Fig 3. Distribution of Consecutive Write-ups

There were 51 occurrences of the ordered triples (i,j,k), where each successive write-up occurred within three sorties of the previous one, out of the 541 total possible, or 9.4%. In addition, sixteen percent (87) fell into the category where there were five or less sorties separating consecutive write-ups.

Results of the distribution of i alone and the ordered pairs (i,j) can be combined to form a model. (The ordered triples (i,j,k) are not included in this model because the model would then lose its simplicity). This model provides probabilities for how many sorties will occur before another discrepancy is encountered, given a known initial separation, for inclusion in the AFHRL's maintenance decision diagnostic model, and is shown in Figure 4.

Analysis of the repeat/recurring coded write-ups resulted in the following statistics. Of the 108 aircraft investigated, 39 had a total of 79 write-ups designated as repeat/recurring. Fourteen of these discrepancies occurred immediately following a similarly coded write-up (i.e., three identical complaints in a row). This involved nine of the thirty-nine aircraft. The 79 occurrences represent two-thirds of all the instances (107) where a discrepancy occurred within the next three sorties. The fourteen immediately repeated write-ups represent thirteen percent of the total number of (i,j) pairs where successive write-ups occurred within three sorties of each other.



i,j: number of sorties between radar write-ups

Fig 4. Model of Consecutive Write-ups (i,j)

IV. CONCLUSIONS

This research has shown that a significant portion of all radar discrepancies occur within three sorties of a previous write-up. This would be a result of inappropriate BIT tests, intermittents, false alarms and incorrect maintenance decisions, as previously discussed. Equipment which was undergoing a gradual component failure or tended to fail only under certain environmental conditions would greatly increase the CND rate since this condition would most likely be extremely difficult to isolate during ground testing. Because of the various mission profiles which are flown, not all of the radar system capabilities are exercised on every flight. This could explain the difference between the A model and B-model statistics since certain missions are typically flown in a particular model of aircraft. It would also explain why write-ups do not always occur on consecutive sorties.

The analysis of both total occurrences of radar write-ups and the ordered pair occurrences (i,j) has provided the basis for a simple model. The model indicates that there is indeed a trend in the occurrences of radar system write-ups. The trend is that if a discrepancy exists, there is a good chance that another write-up will occur in the next few sorties, and if another occurs, that it too will be within the next few sorties. This is not to imply that they are all the same write-up; however, the conclusion that they are related might not be inappropriate. The causes for this trend are likely to be those previously mentioned, since actual equipment failures alone of the magnitude necessary to produce the same result are highly improbable.

Write-ups which were identified as repeat/recurring in the aircraft records provide approximations to rates of occurrence. However, actual identification of a discrepancy as repeat/recurring is dependent upon the nature of the write-up, the history information available during pilot debrief and the debriefer's ability to accurately assess the complaint. This information should therefore be used only as a guide.

V. Recommendations for Further Study

The area of repeat/recurring write-ups is one which should be further investigated. It was not covered in depth in this research because of the time committment required to go through the aircraft historical records. In order to obtain accurate data, the actual write-up needs to be traced from its inception (post-flight debrief) to its close-out. Initial study in this area indicates that the computer records are often incomplete, providing no record of actual corrective action performed. An in-depth tracing of these write-ups would provide more data for localizing write-ups and faults to particular LRUs and also provide an indication of how maintenance goes about correcting discrepancies when specific repair information is unavailable.

BIBLIOGRAPHY

1. DI-A-5023. Avionics Diagnostics Pilot Study Plan. Hunt Valley, Maryland: Westinghouse Electric Corporation, February 1982.

2. England, Gordon. "F-16 Self Test/BIT Implementation and Lessons Learned," Built-In-Test Equipment Requirements Workshop. Workshop Presentation IDA Paper P-1600. Arlington, Virginia: Institute for Defense Analyses, August 1981.

3. Herner, Alan E., T. M. Miller, and Russell M. Genet. Diagnostic Errors and Human Factors in Built-In-Test (BIT). Wright-Patterson AFB, Ohio: Air Force Human Resources Laboratory, April 1981.

4. King, M. A., W. S. Demmy, S. A. Shoaf, and A. E. Herner. A Model of the Diagnostic Process for Maintenance of Avionics. Wright-Patterson AFB, Ohio: Air Force Human Resources Laboratory, July 1982.

5. _____. Maintenance Diagnostics Errors Workshop. Compilation of Papers Presented. Wright-Patterson AFB, Ohio: Air Force Human Resources Laboratory, March 1982.

6. Malcolm, John G. and Richard W. Highland. Analysis of Built-In-Test False Alarm Conditions. RADC-TR-81-220. Griffiss AFB, New York: Rome Air Development Center, August 1981.

7. Nie, Norman H. et al. Statistical Package for the Social Sciences. 2nd Edition. New York: McGraw-Hill, Inc., 1975.

8. Pomeranz, J. B. "Confidence in Confidence Intervals," Mathematics Magazine, 55:12-18 (January 1982).

Appendix A

CDS Data Retrieval Program

The following program is a second-generation modification of the CDS standard query labeled "B-RPT". It provides a chronological listing of an aircraft's landing status for each sortie flown, and the assigned work-unit-code and an abbreviated comment on the malfunctioning system if any write-up occurs during post-flight debriefing.

The input parameters as modified are a base identification code, a specific tail number or the word "ALL", and a model identification of "A", "B" or "C", where "C" combines all A and B models. The date range can be changed by modifying the statements labeled RØ and R1.

Appendix A (cont'd)

```
OPTIONS ARE ALLOCATED CORE = *, URGENCY = 30, TIME = *
INVOKE 41380T/F16/YPEADF
L1. LET B1 = #BASE.
L6. LET TAIL = #TAIL-NUMBER.
L7. LET MODEL = #MODEL.
IF MODEL = "A"
   LET MOD1 = "AFA"
      THEN LET MOD2 = "XFR"
         THEN LET MOD3 = "AYL"
            THEN LET MOD4 = "XYL"
               THEN LET MOD5 = "AYN"
                  THEN LET MOD6 = "XYN"
                     THEN LET MOD7 = "AYQ"
                        THEN LET MOD8 = "XYQ"
                           THEN LET MOD9 = "AYS"
                              THEN LET MOD10 = "XYS".
IF MODEL = "B"
   LET MOD1 = "ANF"
      THEN LET MOD2 = "XNL"
         THEN LET MOD3 = "AYM"
            THEN LET MOD4 = "XYM"
               THEN LET MOD5 = "AYP"
                  THEN LET MOD6 = "XYP"
                     THEN LET MOD7 = "AYR"
                        THEN LET MOD8 = "XYR"
                           THEN LET MOD9 = "AYT"
                              THEN LET MOD10 = "XYT".
IF B1 = "USAT"
   LET B1 = "KRSM"
      THEN LET B6 = "VLSB"
         THEN LET B2 = "NVZR"
            THEN LET B3 = "FTFA"
               THEN LET B5 = "RKMF"
                  THEN LET B4 = "FSPM".
IF B1 = "USAF"
   LET B1 = "KRSM"
      THEN LET B6 = "VLSB"
         THEN LET B2 = "NVZR"
            THEN LET B5 = "RKMF".
IF B1 = "NETH"
   LET B1 = "NBBW"
      THEN LET B2 = "CCCC"
         THEN LET B3 = "DDDD".
```

(cont'd)

Appendix A (cont'd)

```
IF B1 = "NORW"
   LET B1 = "UPSA"
      THEN LET B2 = "UPSB"
         THEN LET B3 = "FFFF".
IF B1 = "BELG"
   LET B1 = "BBSZ"
      THEN LET B2 = "MJQB"
         THEN LET B3 = "HHHH".
IF B1 = "DENM"
   LET B1 = "VTLV"
      THEN LET B2 = "IIII"
         THEN LET B3 = "JJJJ".
IF B1 = "PACAF"
   LET B1 = "MLWR"
      THEN LET B2 = "LXEZ"
         THEN LET B3 = "AAAA".
IF B1 = "USAFE"
   LET B1 = "JWEC"
      THEN LET B2 = "BBBB"
         THEN LET B3 = "KKKK".
RØ. RETRIEVE FLEET-BASE FROM YPE WHERE
    (FLEET-DATE = "8112" OR "8201" OR "8202" OR "8203" OR
    "8204" OR "8205" OR "8206" OR "8207" OR "8208" )
    AND (LOC-B-C = B1 OR B2 OR B3 OR B4 OR B5 OR B6)
WHEN RØ.
R1. RETRIEVE M-BREC FROM YPE WHERE
    (B-FLY-DT BETWEEN "811201" AND "821815" )
    AND (B-LAND-ST = "1" OR "2" OR "3" OR "4" OR " " )
WHEN R1.
IF MODEL = "C" GO TO J1.
IF B-SRD NOT = MOD1 AND MOD2 AND MOD3 AND MOD4 AND MOD5
   AND MOD6 AND MOD7 AND MOD8 AND MOD9 AND MOD1Ø RETURN.
J1.
IF TAIL = "ALL" GO TO J2.
IF B-TAILNR NOT = TAIL RETURN.
J2.
S1. SORT WITHIN RØ M-BREC ON B-TAILNR, B-FLY-DT, B-SORT-NUM,
    B-SORT-SEQ
WHEN S1.
PRINT ON FILE #REPORT FOR TEK B-TAILNR, B-FLY-DT, B-SORT-NUM,
    B-SORT-SEQ, B-LAND-ST, B-LAND-ST-WUC, B-LAND-ST-RMK,
    B-ACTUAL-TOFF.
WHEN RØ, R1 EMPTY
    PRINT ON FILE #REPORT FOR TEK "NO DATA FOUND FOR
    CRITERIA SPECIFIED"
END
```

Appendix B

Distribution of Sample Population

Base	Model	Number of Aircraft	Number of Sorties
Hill	A	28	1845
	B	22	2144
MacDill	A	23	1940
	B	17	1467
Nellis	A	12	730
	B	6	399
	Total	108	8525

Appendix C

Single Interval Separation Distributions

Hill AFB

Number of Occurrences (%)

Sortie Separation	A Model	B Model	Combined
1	21(12.8)	18(11.4)	39(12.1)
2	19(11.6)	10(6.3)	29(9.0)
3	15(9.1)	14(8.9)	29(9.0)
4	11(6.7)	12(7.6)	23(7.1)
5	9(5.5)	8(5.1)	17(5.3)
6	7(4.3)	8(5.1)	15(4.7)
7	9(5.5)	6(3.8)	15(4.7)
8	5(3.1)	11(7.0)	16(5.0)
9	5(3.1)	7(4.4)	12(3.7)
10	7(4.3)	6(3.8)	13(4.0)
11	4(2.4)	2(1.3)	6(1.9)
12	2(1.2)	1(0.6)	3(0.9)
13	2(1.2)	4(2.5)	6(1.9)
14	5(3.1)	2(1.3)	7(2.2)
15	3(1.8)	2(1.3)	5(1.6)
16	4(2.4)	5(3.2)	9(2.8)
17	4(2.4)	2(1.3)	6(1.9)
18	-	4(2.5)	4(1.2)
19	2(1.2)	3(1.9)	5(1.6)
20	1(0.6)	3(1.9)	4(1.2)
21	2(1.2)	3(1.9)	5(1.6)
22	1(0.6)	1(0.6)	2(0.6)
23	3(1.8)	-	3(0.9)
24	2(1.2)	2(1.3)	4(1.2)
25	1(0.6)	1(0.6)	2(0.6)
26	-	2(1.3)	2(0.6)
27	3(1.8)	-	3(0.9)
28	2(2.4)	1(0.6)	3(0.9)
29	-	-	-
30	1(0.6)	1(0.6)	2(0.6)
31-35	2(1.2)	7(4.4)	9(2.7)
36-40	4(2.4)	1(0.6)	5(1.5)
>40	8(4.9)	11(7.0)	19(5.7)
Total	164(100)	158(100)	332(100)

Appendix C (cont'd)

MacDill AFB

Number of Occurrences (%)

Sortie Separation	A Model	B Model	Combined
1	35(19.6)	12(11.9)	47(16.8)
2	16(8.9)	17(16.8)	33(11.8)
3	12(6.7)	7(6.9)	19(6.8)
4	13(7.3)	2(2.0)	15(5.4)
5	10(5.6)	3(3.0)	13(4.6)
6	9(5.0)	5(5.0)	14(5.0)
7	8(4.5)	5(5.0)	13(4.6)
8	4(2.2)	2(2.0)	6(2.1)
9	8(4.5)	2(2.0)	10(3.6)
10	4(2.2)	2(2.0)	6(2.1)
11	7(3.9)	5(5.0)	12(4.3)
12	4(2.2)	4(4.0)	8(2.9)
13	2(1.1)	2(2.0)	4(1.4)
14	5(2.8)	2(2.0)	7(2.5)
15	2(1.1)	1(1.0)	3(1.1)
16	3(1.7)	1(1.0)	4(1.4)
17	1(0.6)	2(2.0)	3(1.1)
18	4(2.2)	-	4(1.4)
19	4(2.2)	2(2.0)	6(2.1)
20	2(1.1)	4(4.0)	6(2.1)
21	2(1.1)	1(1.0)	3(1.1)
22	-	-	-
23	2(1.1)	-	2(0.7)
24	1(0.6)	3(3.0)	4(1.4)
25	1(0.6)	1(1.0)	2(0.7)
26	1(0.6)	-	1(0.4)
27	-	1(1.0)	1(0.4)
28	3(1.7)	-	3(1.1)
29	1(0.6)	1(1.0)	2(0.7)
30	-	-	-
31-35	6(3.4)	2(2.0)	8(2.9)
36-40	3(1.7)	3(3.0)	6(2.1)
>40	6(3.4)	10(9.9)	16(5.7)
Total	179(100)	101(100)	280(100)

Appendix C (cont'd)

Nellis AFB

Number of Occurrences (%)

Sortie Separation	A Model	B Model	Combined
1	17(17.0)	8(17.4)	25(17.1)
2	17(17.0)	7(15.2)	24(16.4)
3	9(9.0)	7(15.2)	16(11.0)
4	4(4.0)	2(4.3)	6(4.1)
5	6(6.0)	2(4.3)	8(5.5)
6	2(2.0)	3(6.5)	5(3.4)
7	5(5.0)	-	5(3.4)
8	6(6.0)	1(2.2)	7(4.8)
9	5(5.0)	3(6.5)	8(5.5)
10	5(5.0)	-	5(3.4)
11	4(4.0)	-	4(2.7)
12	3(3.0)	-	3(2.1)
13	-	3(6.5)	3(2.1)
14	1(1.0)	2(4.3)	3(2.1)
15	4(4.0)	3(6.5)	7(4.8)
16	3(3.0)	-	3(2.1)
17	1(1.0)	1(2.2)	2(1.4)
18	-	1(2.2)	1(0.7)
19	1(1.0)	-	1(0.7)
20	2(2.0)	-	2(1.4)
21	-	1(2.2)	1(0.7)
22	1(1.0)	-	1(0.7)
23	1(1.0)	-	1(0.7)
24			
25			
26	1(1.0)	-	1(0.7)
27			
28			
29			
30			
31-35	2(2.0)	-	2(1.4)
36-40			
>40	-	2(4.3)	2(1.4)
Total	100(100)	46(100)	146(100)

Appendix C (cont'd)

All Bases

Number of Occurrences (%)

Sortie Separation	A Model	B Model	Combined
1	73(16.5)	38(12.5)	111(14.8)
2	52(11.7)	34(11.1)	86(11.5)
3	36(8.1)	28(9.2)	64(8.6)
4	28(6.3)	16(5.2)	44(5.9)
5	25(5.6)	13(4.3)	38(5.1)
6	18(4.1)	16(5.2)	34(4.5)
7	22(5.0)	11(3.6)	33(4.4)
8	15(3.4)	14(4.6)	29(3.9)
9	18(4.1)	12(3.9)	30(4.0)
10	16(3.6)	8(2.6)	24(3.2)
11	15(3.4)	7(2.3)	22(2.9)
12	9(2.0)	5(1.6)	14(1.9)
13	4(0.9)	9(3.0)	13(1.7)
14	11(2.5)	6(2.0)	17(2.3)
15	9(2.0)	6(2.0)	15(2.0)
16	10(2.3)	6(2.0)	16(2.1)
17	6(1.4)	5(1.6)	11(1.5)
18	4(0.9)	5(1.6)	9(1.2)
19	7(1.6)	5(1.6)	12(1.6)
20	5(1.1)	7(2.3)	12(1.6)
21	4(0.9)	5(1.6)	9(1.2)
22	2(0.5)	1(0.3)	3(0.4)
23	6(1.4)	-	6(0.8)
24	3(0.7)	5(1.6)	8(1.1)
25	2(0.5)	2(0.7)	4(0.5)
26	2(0.5)	2(0.7)	4(0.5)
27	3(0.7)	1(0.3)	4(0.5)
28	5(1.1)	1(0.3)	6(0.8)
29	1(0.2)	1(0.3)	2(0.3)
30	1(0.2)	1(0.3)	2(0.3)
31-35	10(2.3)	9(3.0)	19(2.5)
36-40	7(1.6)	3(1.0)	10(1.3)
>40	14(3.2)	23(7.5)	37(4.9)
Total	443(100)	305(100)	748(100)

Appendix D

Overall Single Interval Separation Statistics

Base/Model	Number	Max	Mode	Mean	Median	Std Dev
Hill/A	164	61	1	11.3	6.5	12.6
Hill/B	158	135	1	13.6	7.8	17.4
MacDill/A	179	110	1	10.9	5.9	14.2
MacDill/B	101	102	2	14.5	7.4	18.2
Nellis/A	100	34	1 & 2	7.3	5.0	7.0
Nellis/B	46	67	1	8.7	4.0	12.2
Hill/Both	322	135	1	12.4	7.1	15.2
MacDill/Both	280	110	1	12.2	6.4	15.8
Nellis/Both	146	67	1	7.7	4.8	9.0
All/A	443	110	1	10.2	5.9	12.4
All/B	305	135	1	13.1	7.2	17.0
All/Both	748	135	1	11.4	6.4	14.5

Appendix E

Distribution of Write-ups of the Ordered Pairs (i,j)

(All Bases)

Number of Sorties, j, between 2nd and 3rd Write-ups

Number of Sorties, i, between 1st and 2nd Write-ups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	18	21	10	8	4	4	4	3	3	1	4	1	-	1	2
2	15	16	7	4	3	6	1	3	4	2	1	1	2	1	-
3	8	6	6	6	4	-	2	4	-	1	-	3	1	3	-
4	8	2	3	4	3	1	2	3	3	-	1	1	-	1	-
5	4	2	5	2	4	1	3	3	-	1	2	2	2	-	1
6	6	4	3	3	-	-	2	1	2	-	-	-	2	-	1
7	6	2	-	2	1	-	1	2	-	1	3	1	-	-	-
8	4	2	4	1	-	-	-	1	-	3	1	-	2	1	-
9	1	5	2	-	2	2	2	1	1	1	-	-	1	2	-
10	3	1	3	-	1	2	1	-	1	1	-	-	1	1	-
11	1	2	2	-	1	1	2	1	1	-	1	-	-	-	-
12	1	1	-	1	1	-	-	-	1	1	-	-	-	-	1
13	2	1	1	-	1	1	1	-	1	-	-	-	-	1	-
14	5	3	2	-	-	2	-	-	-	-	-	-	-	-	-
15	2	-	-	-	1	2	-	1	2	1	-	-	-	1	1
16	1	1	1	1	1	1	2	-	-	-	1	-	-	-	-
17	1	1	-	1	-	-	-	-	-	1	-	-	-	1	2
18	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-
19	2	-	1	-	-	-	1	-	-	-	1	-	-	-	1
20	-	-	-	2	-	1	-	1	-	-	-	-	-	-	-
21	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
23	-	-	-	-	1	1	1	-	-	-	-	1	-	-	-
24	-	1	1	-	-	-	-	1	-	-	2	-	-	-	-
25	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
28	-	1	1	-	-	1	-	-	-	-	-	1	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
31-35	1	-	-	-	1	2	2	1	3	-	1	-	-	-	2
36-40	-	2	-	1	1	-	1	-	-	1	-	-	-	-	-
>40	7	2	3	-	1	1	-	1	1	3	-	-	-	1	-
Total	100	78	56	38	31	29	28	27	25	19	18	11	12	14	13

Appendix E (cont'd)

Number of Sorties, j, between 2nd and 3rd Write-ups

Number of Sorties, i, between 1st and 2nd Write-ups	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31-35	36-40	>40
1	1	2	3	1	1	1	-	-	2	-	1	1	1	-	-	-	-	6
2	1	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	1	2
3	1	-	1	1	2	1	-	2	-	-	-	-	-	-	-	2	1	5
4	1	-	-	1	-	2	1	1	-	-	-	-	-	-	-	1	1	1
5	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
6	-	1	-	1	1	-	-	-	-	1	-	-	1	-	-	2	1	1
7	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	4
8	-	1	-	1	-	-	-	-	-	-	-	-	-	1	-	1	-	-
9	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1
10	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-
11	1	-	-	-	1	-	-	1	-	-	-	-	1	-	-	2	-	2
12	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-
13	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
14	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-
15	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
16	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	2
17	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
18	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
19	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
20	1	-	-	1	-	1	1	-	-	-	-	-	-	-	-	1	1	-
21	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-
22	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
23	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
25	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
29	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31-35	1	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
36-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>40	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	2	-	1
Total	13	9	7	10	10	8	2	6	7	2	3	3	6	2	1	15	9	22

VITA

Kim A. Riche was born 26 February 1952 in Los Angeles, California. He graduated from high school in Los Altos, California in 1970 and attended the University of Colorado from which he received the degree Bachelor of Science in Electrical Engineering in May 1974. Upon graduation, he received a commission in the USAF through the ROTC program. He was employed in the High Reliability Microwave Communications Division of Airtech Industries, Sunnyvale, California until called to active duty in January 1975. He completed pilot training and received his wings in December 1975. He then served as a T-38 instructor and check pilot in the 97th Flying Training Squadron, Williams AFB, Arizona, and as a KC-135Q aircraft commander in the 349th Air Refueling Squadron, Beale AFB, California until entering the School of Engineering, Air Force Institute of Technology, in June 1981.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GE/EE/82D-56	2. GOVT ACCESSION NO. AD-A124749	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ANALYSIS OF F-16 RADAR DISCREPANCIES		5. TYPE OF REPORT & PERIOD COVERED MS THESIS
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kim A. Riche Capt USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT/EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Human Resources Laboratory (LRLA) Wright-Patterson AFB, Ohio 45433		12. REPORT DATE December 1982
		13. NUMBER OF PAGES 42
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release: IAW AFR 190-17.

Lynn E. Wolaver

LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

4 JAN 1983

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

F-16 Radar System
AN/APG-66 Radar
Aircraft Radar
Built-In-Test (BIT)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

One hundred and eight aircraft were randomly selected from three USAF F-16 bases and examined over the time period 1 Dec '81 to 15 Aug 82. These aircraft included 63 F-16As and 45 F-16Bs and encompassed 8,525 sorties and 748 radar system write-ups. Of the 748 discrepancies, over one-third of them occurred within three sorties of each other and half within six sorties. Sixteen percent of all aircraft which had a discrepancy within three sorties had another write-up within the next three sorties. Designated repeat/recurring write-ups represented one-third of all the instances in which the write-up separation interval was three

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20 (Continued)

sorties or less. This is an indication that maintenance is unable to correct equipment failures as they occur, most likely because the false alarm rate is too high and maintenance is unable to duplicate the error conditions on the ground for correct error diagnosis.

END